REPORT ON A SHORT TRIP TO CERTAIN SNOW AND AVALANCHE RESEARCH STATIONS IN WESTERN EUROPE: SEPTEMBER 1959

M. Martinelli Jr.

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and

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INTRODUCTION

H. C. Storey (Washington office) and M. Martinelli, Jr. (Rocky Mountain Station) made a trip to snow and avalanche research stations in France, Switzerland, and Austria during September, 1959. This report reviews the highlights of the trip and outlines, in a general way, the work that is being done and the people currently engaged in snow and avalanche research in the areas visited. If the report aids in developing direct contacts with the European scientists or creates a better understanding of the work being done in Europe, it will serve its purpose.

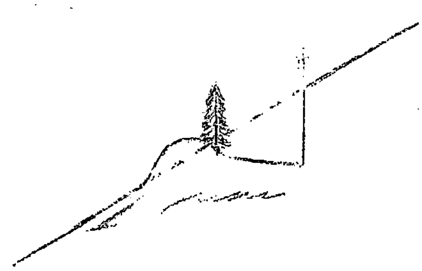
Prior to this trip to the snow laboratories, the authors attended the 1959 meeting of the International Association of Scientific Hydrology, (IASH) at Hannover-Münden, Germany. The proceedings of this meeting (consisting of a symposium on water and woodlands and one on lysimeters) are printed and a copy is available in the Washington office of the Forest Service. Copies may also be purchased from the secretary of the Association, Professor L. J. Tison, 61 Rue des Ronces, Gentburgge, Belgium. Cost of the two volumes is $9.00. Papers appear in either French, German, or English. All of the Russian papers are in English.

EUROPEAN SNOW AND AVALANCHE RESEARCH STATIONS

Forest Research and Experiment Station of the National School of Waters and Forests - Grenoble, France

(Station de Recherches et Expériences Forestières de l' Ecole Nationale des Eaux et Forêts - Grenoble, France[1/])

The first day was spent with Monsieur L. Garavel of the Station de Recherches et Expériences Forestières de l' École Nationale des Eaux et Forêts. His principle interests were torrent control, avalanche prevention, and reforestation. We were able to see only the first two activities because of time limitations. However, other workers in Europe told us the French were very advanced in their high altitude planting methods and techniques. Mr. Garavel discussed the planting program a little and indicated that they use terraces to do most, if not all their high altitude planting. Trees are carefully chosen to get those from a climate and exposure similar to the planting site. They are planted in the terrace where the cut bank changes to fill (see sketch below). Larch and spruce seem to be the principle species planted.



1/ Main headquarters are at 14 rue Girardet, Nancy, France.

Torrent Control - During the afternoon of September 15 we visited an area above the village of Chantelouve to see the torrent control program. The village is located on the alluvial cone formed by a stream draining a steep area where much of the upper part of the watershed is bare rock in the form of cliffs. The work here was very extensive and expensive, not only to install, but to maintain. The plan for protecting the village seemed to be as follows:

(1) High up on the ridge, barriers were built in the stream channel. These were made of stone with wire mesh holding the stone in place (gabion-type construction). Concrete or logs were used to armor the upstream faces of these structures to keep rolling rocks from breaking the wire and releasing the material confined therein.

(2) On the upper part of the alluvial cone the stream was diverted from its "normal" path by a stone wall lined with concrete. A low spot in this diverting wall allowed some of the "lava" (mud, rock, and water) to overflow onto the cone.

(3) This "lava" was slowed down and debris allowed to settle out by the use of numerous stone walls. These were also of gabion construction, armored on top and one side with logs to protect the wire. They are continually being buried or damaged by the "lava".

(4) The new channel which carries most of the flow was stabilized at about 12 to 13 percent slope by gabion type structures across the channel. There was one of these every 15 to 20 feet.

(5) Farther down on the cone, where the road crossed, the stream was confined between parallel stone walls. Debris had to be cleaned from the road after each storm.

(6) Below the village the stream was routed across the cone to its regular channel by means of an accumulating wall.

All of these structures have to be checked each year and most should be checked after every large storm. New structures are built as needed and repairs made on old ones. There has been no damage in the village since these works were completed. The quality of the dry masonry in the walls and dams was outstanding.

Most of the structures and techniques seen here were used years ago in several places in the United States. Many have been abandoned in this country because of the cost of maintenance. There seemed to be no objectivity in the approach to this problem in France. Structures were put in and if they proved inadequate, more were built until the desired result was achieved. It is not clear to us whether it is known what the minimum acceptable program would be for this area nor if this could be determined for other areas with similar problems. Costs for installation and maintenance were very high.

Avalanche Forecasting - The next day was spent in the vicinity of Beaufort, France. In the morning Mr. Sales of Electrique de France (E.D.F.) discussed the avalanche warning system for the French Alps and showed us one large, active avalanche path which had been stabilized with nylon nets.

The avalanche warning system for the French Alps has just recently been moved from Chamonix to the E.D.F. office in Beaufort. This organization issues forecasts and prospectives at weekly intervals except during periods when the danger is high or changing fast. Then reports are issued as often as the occasion demands.

Snow and weather data are transmitted by telephone and wire to Mr. Sales by a great many local observers all over the French Alps. He makes the forecasts from these data. The forecast is transmitted to the public via radio and newspapers by the Weather Bureau, not E.D.F.

Many climatic and snow pack conditions must be considered when forecasting avalanche conditions. French forecasters, like their counterparts in the United States, vary in the weight they give the various factors. Mr. Sales feels that snow pack temperatures are very important in determining avalanche conditions because they influence the rate of change in the crystal structure of the snow pack. Observers in the E.D.F. network take snow temperatures and send them in as part of their regular reports. Mr. Garavel,

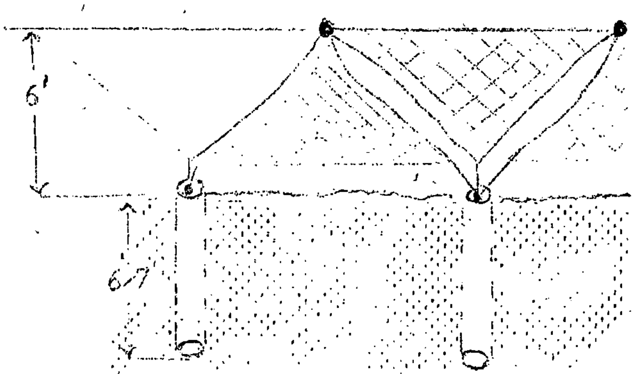
on the other hand, feels the following things are most important in determining avalanche hazard: (1) amount of new snow, (2) wind action, (3) air temperature, and (4) structure of snow in the pack.

Mr. Garavel has worked out an objective system using the depth of new snow in a three-day period at certain key locations to forecast avalanche hazard for other areas in the neighborhood. He has also noticed a pattern to the release of avalanches with given types of storms. That is, certain avalanches run first, then others, and then still others in a detectable pattern. This type of analysis is based on data from cards sent to Mr. Garavel by many hundreds of observers. These cards are sent as soon as an observer sees an avalanche run. Time of avalanche, type of avalanche, location of fracture line, location of toe of avalanche, and numerous other features are checked on each card for each avalanche. Every avalanche in the French Alps is numbered and every couloir is lettered. Avalanches are reported by number to avoid the confusion of local names.

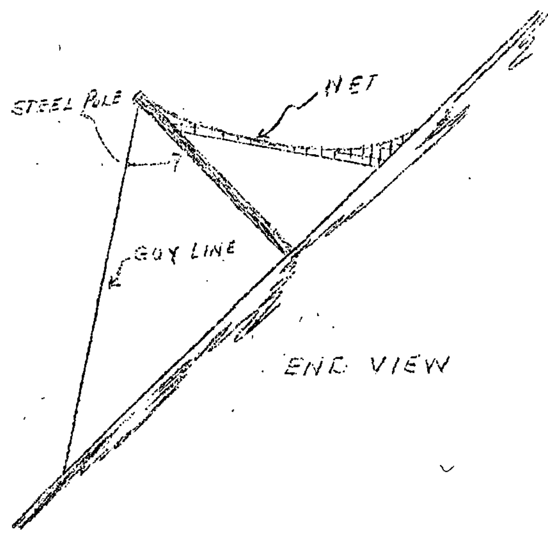
The central avalanche forecasting center at E.D.F. in Beaufort plots snow profiles (each 2 weeks), ram profiles, air temperature, wind speed, etc. in much the same manner as the U.S.F.S. avalanche forecasters. This is the system developed and perfected at Davos, Switzerland and in general use.

Artificial Release of Avalanches - The French are using rockets, grenades, and shell fire to release avalanches artifically. They are also planting land mines before snow fall in some bad spots. These mines can be released electrically during the winter as the occasion demands. Several batteries of these mines are set in such a manner that remote firing can be done several times each winter at the same place.

Avalanche Prevention - Nylon Nets - A field trip was made to a large avalanche path above the village of Beaufort, France. This avalanche crosses the road leading to an important dam. Since access to the dam is necessary all winter, the path has been stabilized with structures which consist of nylon nets supported by steel poles.



FRONT VIEW



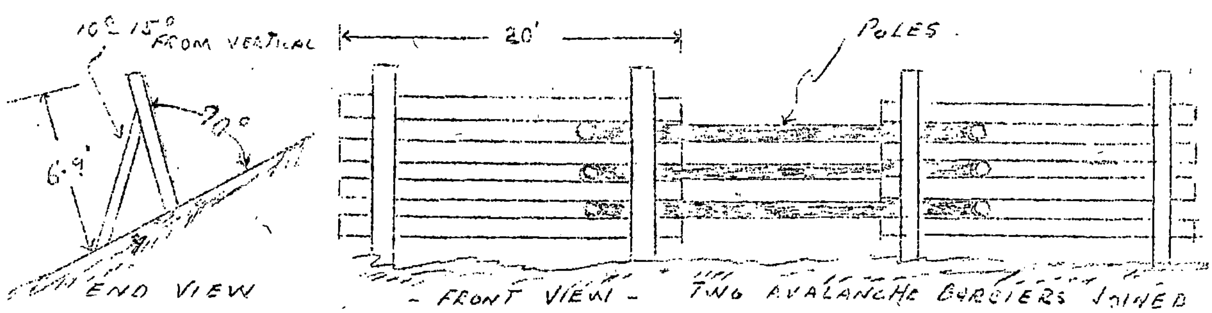
The nylon straps that make up the net have a tensile strength of 7 tons. Recent tests indicate that smaller straps may be adequate. The steel support poles are set at about a right angle to the slope. Steel cables from the top of the poles to anchors below the nets keep the barrier from falling up slope when snow loads the lower part of the net. When natural supports are available, the nets are hung from a horizontal cable and no poles are used.

These nylon nets are lighter and more flexible than wood or metal structures. However, they are subject to cuts from falling rocks and to damage from ultra violet rays from the sun. In areas where falling rocks are a problem, wooden fences are constructed upslope from the nylon nets to retain the rocks. The deterioration from ultra violet light is being reduced by materials painted over the nylon. Mr. Sales and Mr. Garavel seem to feel the nets will last 15 to 25 years under present conditions.

The net barriers we saw were anchored to iron spikes driven into logs buried in the ground. The anchor logs were 10 to 12 inches in diameter and 6 to 7 feet long. They were buried so just the top of the log was at ground level. This top was reinforced with an iron band and had a large iron piton driven into it. Where rock is present, anchors are attached to the rock. There were well over 500 nets on this one avalanche path. All the material had been transported to the site by helicopter. Five men worked one summer to make the installation. Except for areas of bare rock, all the former avalanche path had been planted to spruce and larch.

Avalanche Prevention - Rigid Structures - Above the village of Celliers we visited another avalanche path. This was very steep grassland with an avalanche path aimed straight at the village. The path was being stabilized by the use of rigid structures.

A fabulous number of structures had been built in the area. The entire upper part of the avalanche path was studded with barriers designed to roughen the terrain and to hold the snow above it in place. Wood, steel, and a combination of the two were used to build the structures. Most of these were only about 20 feet long; however, in a few cases these short segments were hooked together by poles to make longer barriers (see sketch below).



When these short units are used alone they should be arranged in a staggered pattern to avoid creating lanes where the snow can pass between barriers. Barriers should be more numerous in areas of convex terrain where snow cover is under tension; they can be more sparse in concave terrain where the snow cover is in compression.

At one place on this avalanche path below a one-lane summer work road there was a steel structure built of 6-inch I beams spaced 12 to 15 feet apart and fully 15 to 18 feet tall. Heavy steel mesh was wired and bolted to the I beams to form a barrier. The beams were guyed on the uphill side. It seemed inevitable that these guy lines will offer serious problems next spring when settlement takes place in the snow covering them.

In addition to the engineering structures, this area was being terraced and planted with larch and spruce.

Personnel and Proposed Studies - Mr. Garavel has three or four professionally trained men working with him. Two are meteorologists who are accumulating and analysing the weather data from the French Alps. The others I would guess are either engineers or foresters. Mr. Garavel is working on an electrically heated snow gage to catch blowing snow. He is also interested in doing a wind tunnel study of the effect of fences and terrain on the wind movement of snow. The research station at Nancy is interested in a study of the vegetation to be used to stabilize avalanche paths. It was pointed out that this study would have more general application if the effort were made to determine the form and characteristics of the vegetation most successful in stabilizing avalanche paths rather than just a study of the relative merits of the various local species.

The French are making good use of helicopters to carry supplies and equipment into steep, rough terrain. They use the Alouette mostly and have had good results up to 3000 M (9-10,000 ft.).

Swiss Snow and Avalanche Research Institute - Davos, Switzerland

(Eidg. Institutes für Schnee-und Lawinenforschung - Weissfluhjoch ob Davos, Switzerland)

Personnel and Organization - This is probably the focal point of snow and avalanche research in Europe. Their organization is flexible, following the abilities and interests of the scientists at the Institute rather than adhering to any predetermined pattern. At present, Dr. M. de Quervain is Director of the Institute. His staff consists of about 25 people and is organized as outlined below:

I. Weather, snow cover, and avalanche

Dr. Th. Zingg is in charge. He also acts as associate Director of the Institute. There are three men helping Dr. Zingg; one handles the avalanche reports and forecasts.

II. Construction for avalanche protection

Mr. André Roch is in charge. He has two engineers, two technicians, and a draftsman helping him.

III. Biological aspects of avalanche protection and prevention

Mr. H. R. In der Gand is in charge. He has three helpers and the promise of another next year.

IV. Hail research - controlled climate wind tunnel

Dr. Roland List is in charge. He has two helpers.

V. Crystalography

Dr. M. de Quervain is in charge. He has no helpers at this time.

VI. Clerical and shop help

There are three girls on the office staff and about 3 to 5 machinists and instrument specialists.

All of these sections operate from a laboratory located 3,600 feet above the town of Davos-Dorf. The people all ride the cable car to and from work each day - a trip of about 22 minutes one way.

At the time of our visit Dr. de Quervain was in Greenland, and Dr. Zingg, the Acting Director, showed us the laboratory and most of the field experiments. Dr. Zingg is a trained geologist and meteorologist. His interests are in alpine weather, snow conditions, and the metamorphism of snow. He seems to be carrying much of the administrative load at the Institute since the Director is away for long periods on international expeditions and committee functions.

Weather, Snow Cover, and Avalanche Program - Dr. Zingg's section on weather, snow cover, and avalanche work handles the avalanche hazard forecast for all of Switzerland. This set-up is the prototype for other forecasting services in the French Alps and

the Vorarlberg of Austria. The Swiss avalanche observers report to the forecasting center over a special teletype circuit rather than by telephone and wire.

Snow cover investigations near Weissfluhjoch have shown density to be very homogeneous for large areas. These workers say the best water equivalent data are obtained by measuring the density of the snow pack in one place and then getting <u>many</u> snow depth readings. They have found snow density to vary only about 2 percent over a considerable area. Dr. Zingg determines density from a series of vertical samples using a single 500 ml. aluminum cylinder. He then probes to get depth each 2 meters on a series of transects until he has two or three groups of 100 probes each. These depths are averaged in groups of 100 to get the average depth of snow in the area in question. On plots of about 15 acres area they have found it necessary to take 200 depth measurements to obtain an average accurate to $\pm$ 2 inches (water equivalent) for snow depths of 3 to over 20 feet.

A detailed study was made of the water equivalent of the snow cover on two test fields, each about 7 to 10 ha (17 to 25 Ac.) in area. One field was on almost level terrain; the other was on very steep terrain. A Wild ground-based camera was used to make oblique stereopairs for each of the test fields. Photographs were taken before snowfall and at the time of maximum snow depth. The maps drawn from the photographs permitted snow depth to be determined

for these two test fields to an accuracy of $\pm$ 5 cm. It was found that the water equivalent of the two test areas was very close even though there was 2,000 feet difference in elevation. Analysis of the oblique photographs was done at E.T.H. (Technical High School) in Zurich.

Detailed snow profile studies (stratographic sections) have shown that the water equivalent of a given layer of snow is consistant for the entire winter. It changes only after melt starts in the spring.

The Swiss workers have found it hard to probe or to take density samples with a long tube when the snow is approaching isothermal conditions in the spring. They just don't sample during this period except for special studies. This is undoubtably the same condition that causes so much trouble with the Mt. Rose sampler in spring in the Colorado Rockies.

Dr. Zingg's section also takes the routine weather observations at the Institute building and the more complex snow pack data for determining avalanche hazard. The latter are taken at a special test field in the middle of a large flat area about 1,000 feet below the Institute. Here they have an electric resistance device to measure settlement of the various snow layers, a lysimeter to measure melt water during spring melt, a place to make fortnightly stratographic sections of the snow cover, standard weather instruments, and several types of storage gages.

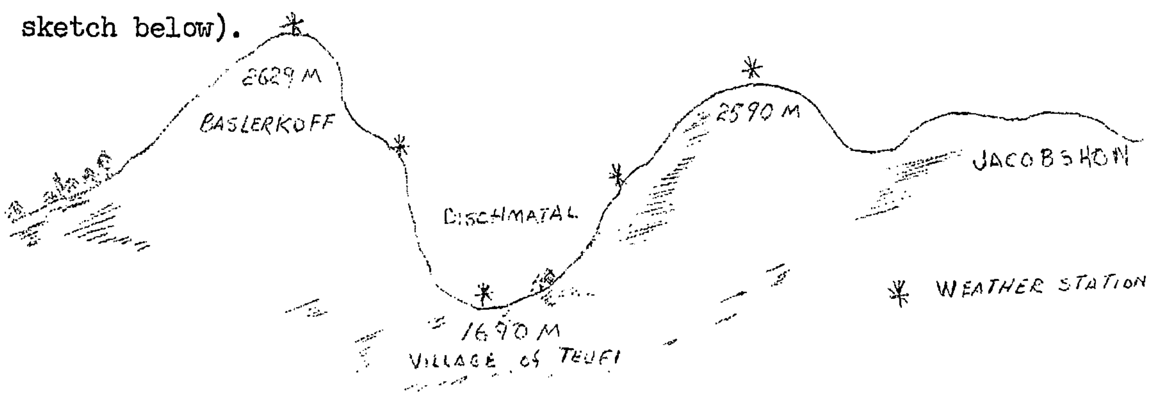
Hail Research - The hail research program is a new one for the Institute. It required the addition of considerable floor space to the original building in order to accomodate the new wind tunnel. Hail damage is a problem in parts of Switzerland and the project at the Institute is set up to study hail stone development under controlled conditions. The stones are grown in the test section of the wind tunnel. Thin sections of the stones are then analysed under polarized light in a cold laboratory to determine crystal structure.

The controlled climate wind tunnel has a test section of 25 x 25 cm. The rest of the tunnel is 50 x 50 cm. The test section is in a vertical position contrary to many wind tunnels which have the test section in a horizontal position. The entire tunnel was built by the shop people at the Institute after 3 years of calculations by Dr. List to develop the specification.[1/] The tunnel is built in sections. This makes it easy to replace the test section or to enlarge the tunnel. Temperature conditions in the tunnel are controlled by a large refrigeration unit and a heating coil. Air is cooled first, then heated to the desired temperature since the smaller bulk of the heating unit permits more rapid adjustment. Humidity is also controlled. The complete controlled climate wind tunnel costs about $40,000.

1/ Dr. List thinks the people at the Canadian National Research Council are outstanding authorities in the field of wind tunnel construction and development.

The hail research program is set up as a purely physical approach. The meteorological implications of the work are not being considered at this time.

Avalanche Prevention, Wind Baffles, and Reforestation - A three way study involving meteorology, structures, and reforestation is in progress on the slopes of the Dischmatal (a valley S.E. of Davos-Platz). Dr. W. Nägeli of the Swiss Federal Forest Experiment Station, E.T.H., Zurich, is in charge. Dr. Zingg and Mr. In der Gand are cooperating. Dr. Nägeli's chief interest here seems to be the study of mountain wind patterns. There are five weather stations giving a profile of weather conditions across the Dischmatal (see sketch below).



The wind data from these stations give a profile for the valley. In addition, pibal readings have been taken in the free air from the village of Teufi in the valley. The results of these studies of mountain and valley winds is to be published soon. The instruments used in the study will be described in the special section on instruments at the end of this report.

Mr. In der Gand's cooperation in the project involves the use of structures to break up the continuity of snow cover in the critical zone of several avalanche paths and the reforestation of such slopes to reduce avalanche hazard.

There are three avalanche paths within the test area. One is being left for control. The other two are being "treated" to prevent avalanches. Treatment consists of a large number of wooden structures in or near the fracture zone of the avalanches. In one of the avalanche paths there is a group of solid vertical fences made by nailing boards to 8-inch poles sunk $1\frac{1}{2}$ meters into the ground. These fences (called kolktafeln in German and Paravents in French) are about 3 meters tall and 2 to 3 meters long. They are oriented with their long axis pointing down the slope (at right angles to the drifting winds). Some of the fences were longer at top than at the bottom (giving greater effective area as the snow accumulates) and some are longer at the bottom than at the top (most effective when there is no snow on the ground). Both types are expected to disturb the uniformity of the snow cover in the accumulation zone of the avalanches as the result of wind scour around the fence and deposition immediately behind it, thus breaking the continuity of the snow cover and reducing the avalanche potential.

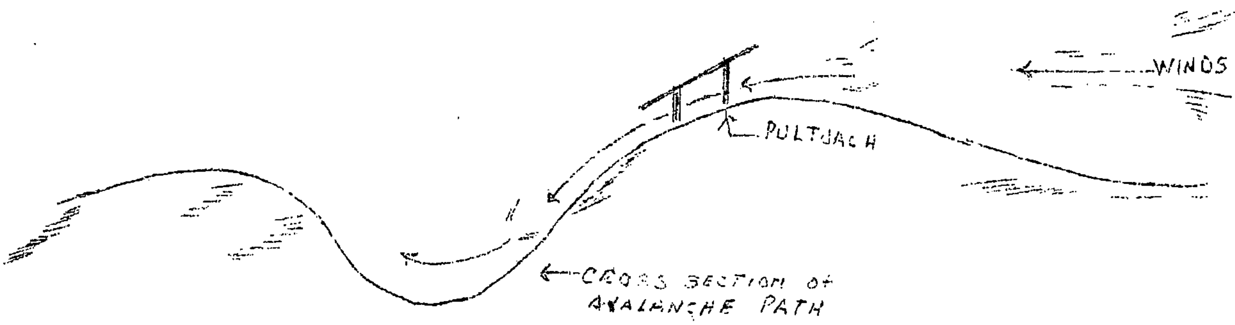
In the next avalanche path the structures were of two general types. One was composed of two sloping wooden faces which gave the appearance of an "A" when viewed from the end. This type was

modified by varying the slope of the faces. The other type of structure was made up of two wooden faces at right angles to each other in the form of a cross. These are called kreuzformige kolktafeln in German and paravents en croix in French. The "A" structures were about 2 m. tall; the cross structures were 2 to 3 meters tall.

All of these fences were expected to disturb the uniformity of the snow cover in the accumulation zone of the avalanche as the result of wind scour around the fences and deposition immediately behind them. These structures were all grouped in the fracture zone of the avalanche path - just where the slope of the terrain increased. They were placed very close together - never more than 4 meters apart - often closer.

In addition to these structures placed in the avalanche path at or near the fracture zone, other structures were placed on the ridges where cornices form. One type of "ridge structure" was shaped like a shed roof. (Called pultdach in German and pupitre in French). These are oriented so that the wind blowing between the roof and the ground is accelerated and directed into the avalanche path. Thus the snow that normally would form a cornice in the lee of the ridge is carried across the avalanche path by

the accelerated winds. The other type of "ridge structure" was a snow fence to accumulate snow in a safe area upwind of the avalanche accumulation zone.



Mr. In der Gand is also using this area for experimental tree planting. Planting was started high on the slopes at what was considered the former tree line (before cutting and grazing lowered it) and then only on the ridges between the avalanche paths. As time goes by he plans to work down the slope and out into the avalanche paths. The idea is to get trees established at the upper end of the avalanche paths first, then in the path itself.

This whole area has been photographed by the same system of oblique photos described earlier. A detailed map will be made of the test area including the three avalanche paths from the photographs. Later it will be rephotographed to determine tree growth and other changes brought about by the treatment. The Swiss are very enthusiastic about this system of photogrammetry using ground based obliques.

Dr. Nägeli has 6 men full time on this project. All are equivalent to Ranger School graduates. He, himself, spends from 3 to 6 weeks each summer doing field work on the project.

Reforestation - Snow Creep Areas - Mr. In der Gand also has a complex experiment under way at two elevations on the Dorfberg, a mountain near the Weissfluhjoch. He is trying to determine the precautions necessary to get survival and establishment of trees in the Swiss Alps. Apparently the major problem in tree establishment in non-avalanche areas is snow creep, snow gliding, and settlement. Among other things the experiment on the Dorfberg is set up to test:

(1) Two species -- spruce and larch.

(2) Methods of planting -- no treatment, planted in scalped areas, planted on terraces.

(3) Presence or absence of artificial barrier to stop snow creep and gliding.

(4) Additional treatments are superimposed on the above 3; such as size and shape of terraces, spacing and location of terraces, species and depth in ground of the poles used to prevent creep and gliding.

Each treatment is replicated twice at each of the two elevations being studied. Each individual plot is about 10 meters square; there are 33 treatments. This appears to be a well designed and executed study. It should give very interesting information.

Planting is done using a machine to prepare the site and 8 to 9 men to plant. Even on very steep terrain this combination plants 800 to 900 trees per day. Trees are raised in peat or wire mesh pots in the nursery and are planted in these pots in the field. Each tree is from a known mother tree and the race as well as the species is recorded. Although planting potted trees means more bulk to be transported to the planting site, it permits planting any time of the year.

Department of Forest Engineering for Torrent and Avalanche Control

(Forsttechniche Abteilung Fuer Wildbach und Lawinenverbauung
Wilhelm Greil Strasse 9, Innsbruck, Austria)

This research station is interested in reforestation of the upper slopes, structures to prevent avalanches, and torrent control. Dr. Aulitzky and Dr. Hilscher (interpreter) summarized the research program by showing us a series of elaborate scale models of all the major projects. Later during a field trip they showed us the research area where plant ecology was being studied in an effort to develop simplified guides to planting procedures. Oberforstrat W. Hassenteufel and Dr. Hilscher showed us the avalanche prevention and control works north of Innsbruck.

The winter of 1950/51 was very severe in much of central Europe. Avalanches were numerous and very distructive. As a result, money is available in Austria for extensive reforestation of mountain slopes, torrent control, and structures for avalanche protection.

There are about 2,000 avalanches and 500 torrents in Tyrolian, Austria that need controlling. Structures to control avalanches cost about one million Austrian schillings (about $40,000) per hectare. Reforestation costs about thirty thousand schillings ($1,200) per hectare. They estimate about two-thirds of the avalanches can be controlled by reforestation. Dr. Aulitzky estimates that about 50,000 hectare need reforestation in Tyrol and about 200,000 hectare in all of Austria. At present about 1,000 hectare per year are being planted in Austria.

Plant Indicators for Reforestation - Phytosociology - Dr. Aulitzky is in charge of an active research program trying to develop simplified guide lines for non-technical workers to follow in an extensive reforestation program. There are large areas in Austria where there is an extensive belt between the climatic tree line and the present timberline due to clearing and subsequent heavy grazing. This is the zone where reforestation is to be concentrated. Their chief research area is near a small village just below Ober-Gurgl. It is in the biotite-plagioclase-gneiss portion of the central Alps. Similar work is planned for a later date in the dolomitic portion of the Alps.

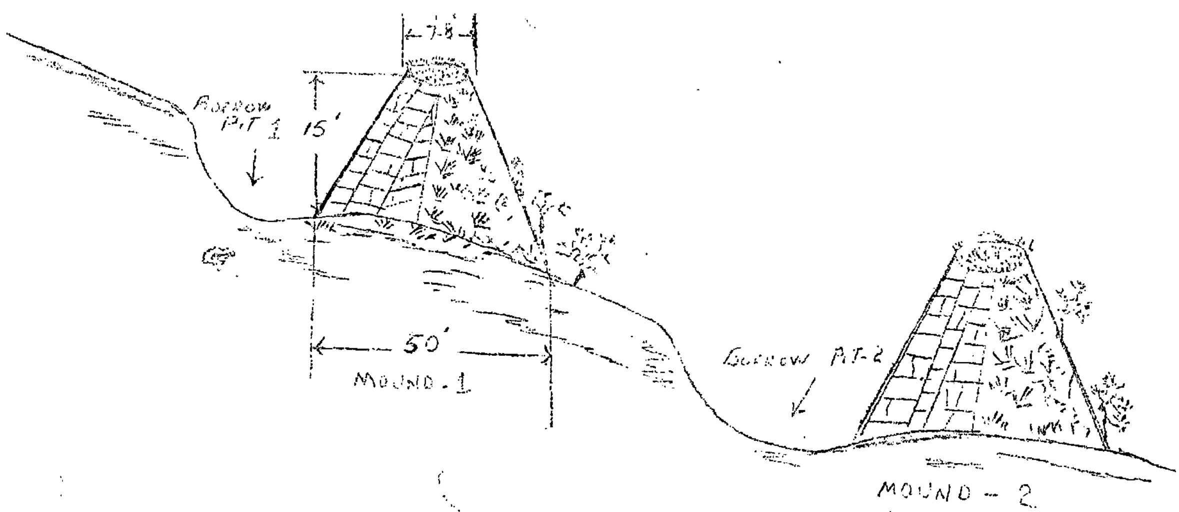
To date, their work indicates that the use of simplified guide lines based on the recognition of certain key plants is practical. In order to use the guides, it is first necessary to determine if the limiting factor for tree growth in the area

involved is snow and wind or heat and drought. After this is determined, certain key plants are used to delineate areas of similar micro climate. The operational steps needed to get successful plantings are keyed to these various microclimates. For example in the snow-wind situation, depth of snow is the important feature. Alectoria ochroleuca and Cetraria nivalis define the areas of bare ground or shallow snow. Alectoria is very definitive - not appearing if maximum snow cover exceeds 5 or 10 cm. Vaccinium uliginosum and Loiseleuria procumbens indicate moderate snow cover and good growing conditions for Pinus cembra. The areas of heavy snow accumulation are covered with Rhododendron ferrugineum (alpine rose) and Vaccinium myrtillus. In order to plant trees successfully on such sites, snow must be accumulated on the Alectoria covered areas; snow must be kept from accumulating on the areas of alpine rose; no special precautions are needed in the intermediate areas. Snow fences (either blowers or collectors) are used to bring about these adjustments in the snow cover.

Snow Fence Patterns - These people have experimented a little with different snow fence patterns. Their results are in keeping with published material. (1) Density of the fence influences length of snow drift; solid fences giving short, deep drifts, open fences giving longer and lower drifts. (2) Fences of a given density give about the same results regardless of configuration. (3) Roughness at the top of the fence is desirable as is flexibility of the fence. (4) Fences with a three dimensional construction are most effective.

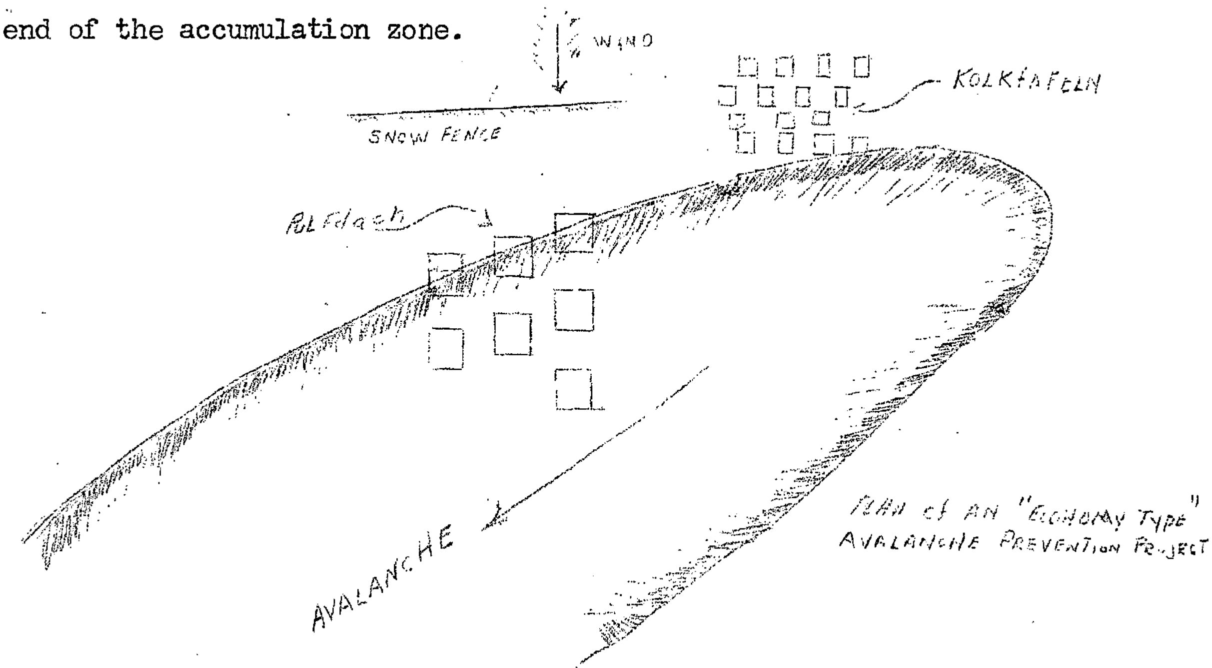
The Institute is also operating a new phytotron. They hope to use this controlled climate building to study the reaction of various plants to climatic conditions typical to the high mountains.

Avalanche Control - Dirt Mounds - The avalanche control work we visited in Austria was on the Nordkette just out of Innsbruck. Numerous avalanches start on the steep, barren upper slopes and sweep down the mountain toward town. Control at the source is considered far too expensive. Instead, they use a system which dissipates the avalanches part way down the slide paths. Conical earthen mounds 50 feet wide at the base, about 15 feet tall, and 7 to 8 feet wide at the top are constructed on benches where the slope of the slide path is less steep. The mounds are built with material dug from the area. The up-hill side is armored with dry masonry and the mounds are planted with shrubs, herbs, and vines. Their placement is dictated by the availability of material. Usually the evacuation of material for the second mound starts at

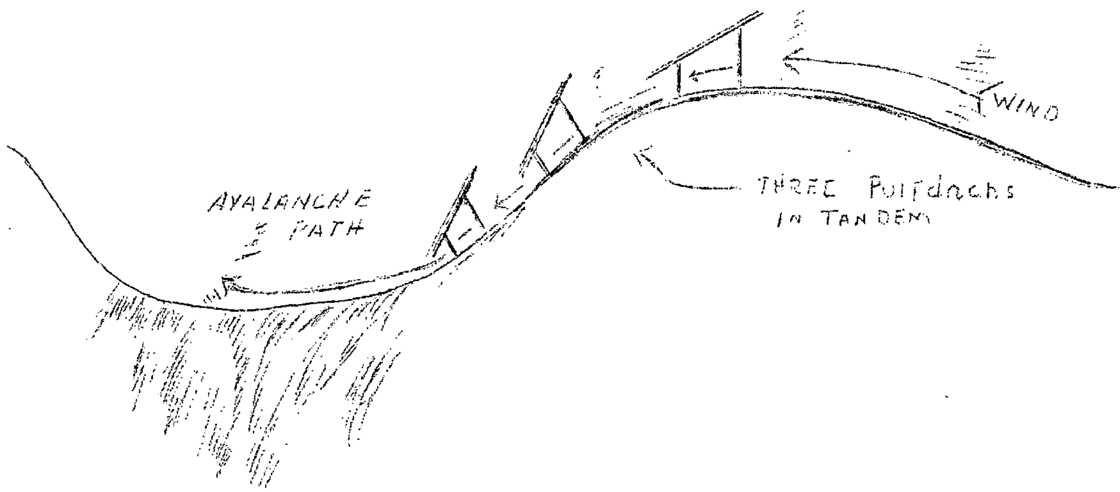


the toe of the slope from the first. They are staggered in arrangement so there is no clear path through the group for the snow to follow. On a large slide path, these mounds would completely fill the path for a distance of about 1/4 mile.

Avalanche Prevention - Wind Baffles - South of Innsbruck we visited an "economy type" avalanche control project. An avalanche that threatened a small village was being controlled by the simplest methods possible. Up-wind from the fracture zone of the avalanche an accumulation fence had been built. It was 12 to 14 feet tall and 300 feet long. Adjacent vertical slats were on alternate sides of the 4" x 4" horizontal members giving a three dimensional effect. On the windward lip of the accumulation zone, pultdachs (sloping shed roofs) were used to prevent accumulation. In particularly bad spots two or three such structures were used in tandem. A series of kolktafelns (vertical solid wood fences) were erected at the uphill end of the accumulation zone.



The pultdachs (shed roofs) should be steeper than the slope of the ground and they should start on the crest of the ridge. Two or three in tandem seem to work well. Posts are used for vertical supports and 4" x 4" timbers for horizontal members. The present ones are $3\frac{1}{2}$ to 5 feet tall on the up-wind side, 6 to 9 feet long (across the wind) and 6 to 9 feet deep (down the wind). The local forester plans to build the next ones even higher on the up-wind end. All these structures were heavily braced with guy wire.



A small reel affair was incorporated into the guy wire on the snow fence so slack could be given during periods of snow settlement.

These structures have been in for several years now and so far there has been no avalanche.

Swiss Institute of Hydrology E.T.H.

(Abteilung fur Hydrologic der Versuchsanstalt fur Wasserbau und Erdbau an der ETH Zurich - Gloriastrasse 39, Zurich, Switzerland)

Mr. Peter Kasser, chief of the hydrology section, discussed his program of work with us. This section has some 6 to 10 field groups doing both research and routine field work on hydrologic problems in Switzerland. Mr. Kasser's office handles the routine streamflow forecasts from snow melt and will soon undertake streamflow forecasts based on short term weather forecasts.

Most of the field work is done in the spring and fall when data on the mass budget of numerous glaciers are taken. Longitudinal and transverse profiles of the glaciers and more recently aerial and ground stero-photogrammetry permit detailed mapping of the study glaciers.

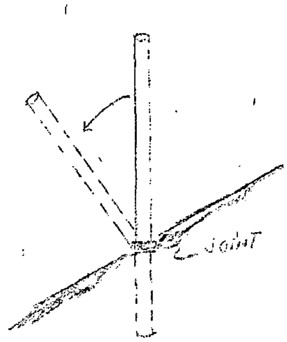
As part of the research program they are making a detailed statistical study of the number of ablation measurements needed to get a given accuracy. They are also using a type of dye dispersal technique to measure velocity of flow in melt-water streams flowing on the glaciers.

This group seems to be quite active in the field of glacialogy and Mr. Kasser, chief of the section, is most cooperative and willing to oblige. Unfortunately we were not able to see any of their work in the field.

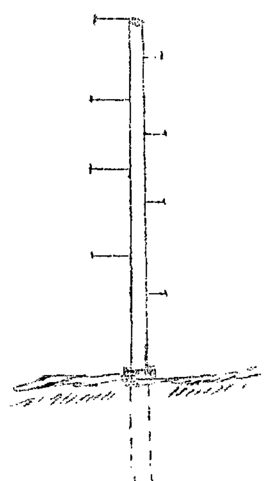
INSTRUMENTATION

Snow depth gages:

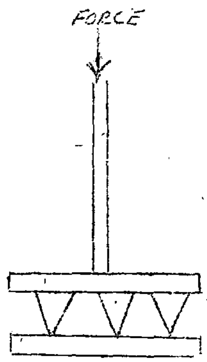
The problem here has always been creep and gliding of snow during the spring. This bends or breaks wooden poles. The Swiss are using 3/4 inch galvinized iron pipe 4 1/2 meters long. These have a joint 1 1/2 meters from one end. The pipes are placed in the ground so this joint is just above the ground line. When the snow starts to creep or glide, the pipe bends at the joint. These can be set back up in summer, or if needed, they could be reset in spring by digging out the snow above the stake. The above-ground part of the poles is 3 meters long. Small horizontal arms extend out from one side of the pole to mark full meters and from the other side to mark 1/2 meters. These can be read to the nearest 10 cm even from a distance using binoculars. Remote reading is necessary for poles on avalanche paths. Poles cost $6.25 each in Switzerland. A few of these were seen with spring-loaded joints so the poles righted themselves after the snow melted. Undoubtedly the self-righting type would cost more than the $6.25 quoted above.



SIDE VIEW


FRONT VIEW

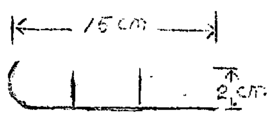
Simple pressure plate:



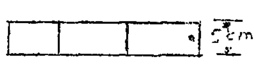
These were used to get the vertical component of pressure in several types of avalanche structures. They consist of a plate with 3 conical points made of steel. The points press into a bronze or copper plate. Maximum pressure is indicated by the size of the holes in the plate.

Another type using calibrated wooden sticks that are bent or broken was being used in Austria. We never did get a very clear idea of how they worked.

Glide shoe:



PROFILE



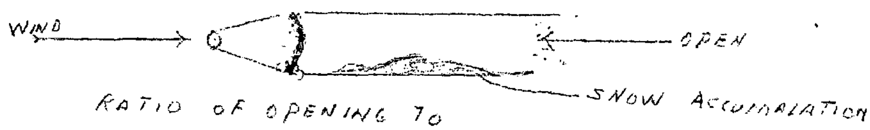
PLAN

This is a homemade device used by Mr. In der Gand to measure the sliding or gliding of snow over a grass surface. It is made of aluminum with the size and configuration shown in the sketches. The upturned tip helps it slide over twigs and small stones. The upright members furnish extra surfaces for contact with snow. The hole in the tail is for attaching a wire that leads through a plastic tube to a buried instrument that makes an electric contact for each mm of movement. This electric impulse operates mechanical counters located in a cabin at some central location.

Mr. In der Gand has a hundred or more of these glide shoes scattered throughout his planting test site on the Dorfberg. This year will be the first full test of the whole system including the remote counters.

Snowdrift meters:

There are no "standard" units. Dr. Zingg at Davos is experimenting with a plexiglass cylinder with a conical inlet on one end. This is copied from the basic design used by the French Antarctic group.



RATIO OF OPENING TO INSIDE AREA ABOUT 1 TO 50.

Mr. Garavel at Grenoble is experimenting with a snow drift meter that is heated electrically. It uses a tipping bucket rain gage to measure the melt water.

Weather instruments:

(1) Bellani spherical pyrometer - This is an evaporating type radiometer that uses alcohol rather than water so it is not bothered by cold weather. The whole instrument is supported at about head height and is fully exposed to the atmosphere. The Swiss have been using one for 4 to 5 years and are happy with it. For more information contact Dr. W. Morikoter, Observatory, Davos-Platz, Switzerland. Cost is about $112.

(2) Theodolite for pibal observations - Dr. Zingg is using a Kern instrument developed before World War II and used extensively since then by Swiss meteorologists. The outstanding feature is a mechanical transfer of azimuth and elevation to a paper mounted at the base of the instrument. The operator never takes his eye from the telescope. When the time signal sounds for a reading (1 minute intervals usually) the operator just pulls a lever and the azimuth and elevation angles are recorded by a pin prick on the paper. A reset rachet allows the operator to continue long runs after the points approach one edge of the paper. This appears to be a very nice instrument for one-man pibal readings.

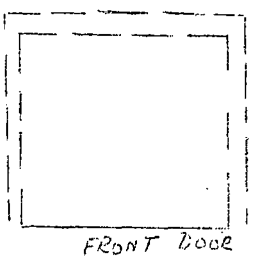
(3) Low response anemometer - Dr. Nägali has some homemade anemometers that respond to winds of 5 cm/sec. The cups are 1/2 of ping pong balls. There are 6 of these cups arranged in two groups of 3. These anemometers are run with a wind vane and an automatic circuit that records wind speed and direction each minute as pin pricks on a traveling paper chart. These are used only in summer.

(4) Propeller type anemometer - Similar to the Aerovane except the cheaper model has a direct drive between the anemometer, wind vane, and the recorder. The more expensive type has a remote recorder for direction and velocity as well as an indicator for these values. Both instruments are available from SIAP (Societa Italiano Apparecchi Precessioni) Bologna, Italy. The direct drive unit (V.T. 126) sells for $525 complete with recorder. The other sells for $1,000 with recorder.

This company has been furnishing the Swiss with weather instruments for several years and has given good service and supplied very good equipment at reasonable prices.

(5) Humidity element for hygrothermograph - German companies are now supplying synthetic elements for the humidity portion of hygrothermographs. The new units stay in calibration for long periods and have replaced the hair element.

(6) Weather shelter for windy and snowy sites - Still no satisfactory solution. The Swiss use a double-walled shelter made of aluminum-covered wood panels arranged as sketched. A double wood bottom is used to prevent excess heating from reflected energy from the snow below the shelter. On windy days snow filters through the cracks in the walls.



TOP VIEW
DOUBLE WALLED
INSTRUMENT SHELTER

(7) Pyrometer for surface temperatures - The Swiss have a Sieman's instrument that gives surface temperature by the amount of long wave energy emitted from the surface. The Institute just received this instrument and has had no experience with it. They expect to use it to measure snow surface temperatures in the field and for part of the wind tunnel studies on hail development.

(8) Self-developed instruments used by the Austrians - A couple of swinging precipitation gages (Vecto pluviometers). Some with a funnel shaped orifice arranged to catch the vertical component and some arranged to catch the horizontal component. These present nothing new in principle or method of measurement and would not work under moderate to heavy snow conditions.

Another non-conventional instrument was also being tested. This was an attempt to measure the whole complex of factors influencing plants. Sensing elements measured precipitation, dew, temperature, and wind as they affected the plants. At best this type of instrument could only give a ranking to various sites or exposures.

Odds and ends:

Many, many cable systems were being used to transport material and equipment to test areas in the mountains. These were in general use in all the areas visited. They cost about $2,500 - $4,000 in Switzerland and can be moved from place to place for different jobs. A 2 or 3-man crew can erect the supports and terminals needed in less than a week.

Wind generators - used at most of the alpine huts in Switzerland to power the radio and telephone. These are of the three-blade type and have proven very useful and serviceable. It was suggested that they could be used to power electrical equipment and instruments at remote stations in the United States.

Climbing skins for skiis - The Swiss use the term Trima almost as a synonym for climbing skins. These Trima climbers are available in this country for about $14. They attach to the bottom of the ski by plates and leave the steel edges free to help give traction on steep and icy places.

The rumor is that Seligman's book, "Snow Structure and Ski Fields" is to be reissued soon.

SUMMARY

Avalanche control research and practice in Europe falls into three categories: (1) Massive and numerous structures in the slide path to keep the snow from avalanching - this is the most positive if done properly. (2) Wind baffles and fences to interrupt the uniformity of snow cover in the accumulation and fracture zones - less costly but quite effective if done properly. (3) Mounds in the avalanche paths where the gradient slacks off. This system allows avalanches to form and run naturally; however, the avalanche is broken up before the snow gets to areas that are being protected.

Engineers and technicians working with avalanche control seem to consider the type, location, and frequency of control structures more of an art than a science.

Most of the work seen and discussed was either concerned with avalanche control and prevention or the use of plant indicators to define practices and procedures needed to establish trees in areas above the present timber line but below the climatic timber line.

The transport of snow by wind and the influence of terrain in the deposition of this snow is considered important but is not being studied directly.

The very active group at Davos is reluctant to publish anything except highly original work. They have a great deal of information and experience that is available only as internal office reports. Their annual report (in German) does give highlights of current projects and would be of interest to all stations doing snow research.

All the stations visited have people who read English, so there should be no hesitation in corresponding with any of the people mentioned, should the occasion arise.